CMOS Radio

Expanding Moore's Law with Ubiquitous, Silicon-Based Wireless Connectivity

White Paper

Intel Labs

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Intel researchers are creating on-chip smart radio circuits with built-in, reconfigurable wireless network hookups that offer always-on connections, plus the ability to switch automatically and transparently between wired and wireless networks. It's just one illustration of a basic principle: Intel is applying the principles of Moore's Law to benefit entirely new arenas and enable expanded capabilities and performance.

Opportunities: *Wireless Connectivity in Silicon*

Before the advent of digital processing, radios were designed entirely of analog circuitry. As advances with the cost and scale of CMOS technology provided digital processing power, digital signal processing (DSP) began to play a major role in overall communication system designs. Ever-improving DSP techniques have enabled improvements in communications consistent with the predictions of Moore's Law.

Today, we are experiencing the power of DSP techniques through many wireless radio frequency (RF) communication applications. Wireless wide area networks (WWAN, or cell phones), Wireless Local Area Networks (WLAN), and Wireless Personal Area Networks (WPAN) all employ sophisticated communication techniques. Some of these techniques include complex modulation schemes, powerful new error correcting codes, and decoding algorithms to combat the effects of channel fading, and so on. All these techniques are being enabled, cost-effectively, by the increasing capabilities of digital processing, as Intel continues to fulfill Moore's Law. At the same time, CMOS technology and the effects of Moore's Law have enabled digital devices to be produced in high volumes, again in a cost-effective manner, enabling larger markets.

Until recently, high-frequency wireless communications applications have used technology processes such as Gallium-Arsenide (GaAs) to obtain the performance needed from the RF Analog Front End (AFE) circuits. Although these processes provide the functional performance required by radios today, they do not support the same cost/scalability economics of standard CMOS that is reflected by Moore's Law.

Just as Intel's constant drive to realize Moore's Law pushes us to new limits, we are reaching performance thresholds leading to the possibility of new discoveries. The higher switching speeds that result from the smaller geometries being developed in CMOS are enabling the design of analog circuits at very high frequencies, with very good gain and linearity. It is this new frontier where Intel Labs is focusing research on the design of analog RF circuitry, which utilizes the same CMOS process technology and device set that Intel uses to manufacture its microprocessors and chipsets.

This new capability will allow analog circuit designs to scale with the digital capabilities predicted by Moore's Law. Analog solutions implemented in CMOS will achieve high performance, functionality, and bandwidth while maintaining low cost, small size, high quality, and robust architecture across the wireless market.

Intel Research Focus

Intel Labs research is addressing the challenges involved in utilizing a process technology that is optimized for digital switching transistors, at ever-decreasing supply voltages, and synthesizing analog RF circuits. This is a leading area of industry and academic research, and these developments will pave the way for higher degrees of integration for radio chipsets with the attendant cost/scalability benefits.

To aid in the development and rapid deployment of new radio designs, Intel Labs is defining a reprogrammable, reconfigurable, digital communications platform. This development platform will use high-powered processors, DSP processing techniques, and high-speed digital logic to support high data rates (in excess of 100 Mbps) and will be reconfigurable to execute multiple wireless protocols. For example, it will be scalable to allow 802.11a operation, or an experimental Ultra Wide Band (UWB) prototype application operating at speeds greater than 100 Mbps. UWB is an ingredient technology for

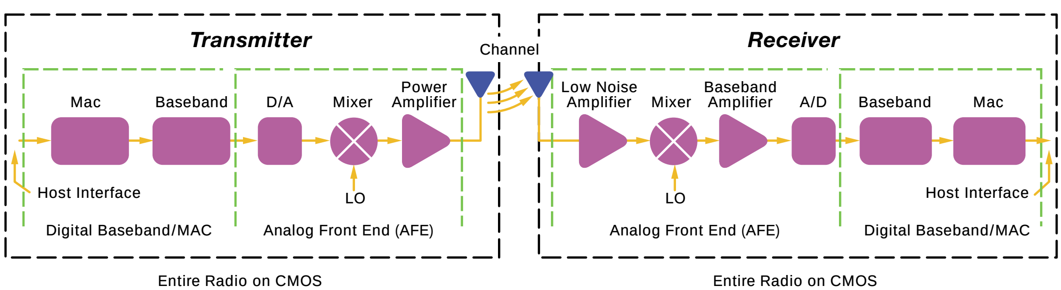

Figure 1. Essential Components of a Wireless Device.

MAC (Medium Access Control)—Enables access to the channel by the host.

Baseband—Low-level data formatting for transmission over the channel to meet protocol/regulatory data integrity requirements.

AFE (Analog Front End)—Transmission/Reception of data in the RF frequency domain.

high-bandwidth wireless communications between devices at very low ranges. Intel Labs is investigating this technology to understand the behavior and potential applications. A hybrid approach capable of supporting up to 400 Mbps is also being proposed. This approach expedites development without requiring expensive, multiple fixed-function implementations.

In support of the reconfigurable digital communications platform, Intel Labs is researching the development of a reconfigurable microcoded accelerator to be used in developing new signal processing algorithms and techniques. The reconfigurable accelerator will use precisely defined computational elements, connected together in a proposed hybrid MESH network topology that can be programmed to execute different communications solutions at an energy-per-computation cost less than that of current DSP solutions. This type of architecture will enable the realization of systems supporting different protocols with improved capacity, robustness, and range in a very flexible manner, while requiring much less energy for computation.

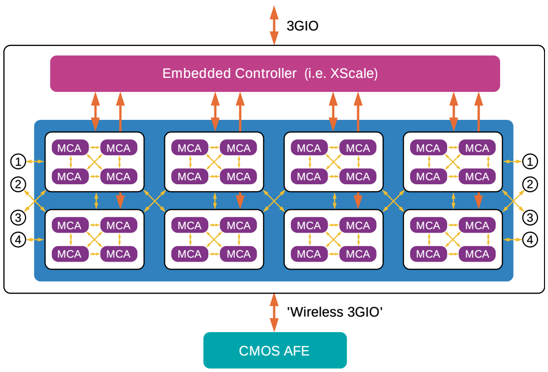

Figure 2. Proposed hybrid architecture using the microcoded accelerator.

The research firm Cahners* In-Stat Group predicts that by 2005 at least 50 percent of over 900 million cellular phones will be data enabled through either WPAN or WWAN next-generation radios. In addition, existing WLAN technologies continue to emerge to support applications with both personal and handheld computers. Users are sending and receiving data content over all these wireless protocols. Today, they must carry different hardware solutions for each wireless frequency or technology, and in many cases they must reconfigure their machines to access data using the required protocol.

Intel is developing the "radio of tomorrow." As we move into the future, the entire radio has the potential of being integrated on a single chip. By developing reconfigurability and reprogrammability on a single hardware solution, along with the supporting Analog ingredients in CMOS, users will have a wireless subsystem that employs multiple AFEs at multiple frequencies supporting multiple protocols (for example, WWAN, WLAN, and WPAN).

Looking Forward

The Intel vision will be achieved when all RF functionality becomes part of an existing component. For notebooks, the "component" may be the existing chipset. For smaller computing devices, it may even be the processor. As Intel applies its silicon technology across a new geography of computing and communications paradigms, a more integrated continuum of computing and communications services is made possible.

Expanding Moore's Law,
Expanding the Power of Silicon

Moore's Law started as a simple observation. It has since become a beacon for the electronics industry, guiding the efforts of chip developers, and showing the rate of progress that must be maintained in order to remain competitive. Now, Intel is expanding Moore's Law to accommodate not just increased transistor count but also the rising complexity of silicon-based devices and the convergence of additional devices and technologies integrated onto the chip.

Intel's on-going commitment to make Moore's Law a reality enables rising performance, lower costs, and the convergence of such technologies as Microelectromechanical (MEMS) Systems onto silicon, making technologies such as silicon-based sensor devices and ad hoc sensor networks an exciting reality. By applying the principles of Moore's Law to new classes of functionality, Intel's research is bringing about a new computing and communications geography, making these technologies more affordable and widespread, and opening the door to broad new areas of innovation. And in doing so, Intel is ensuring that Moore's Law remains in effect for decades to come, through a combination of transistor count, complexity, and convergence.

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About the Author

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